metic, such as was seen in diagrams of thrust, pressure, speed, and so forth. But this would take care of itself provided linear drawing were taught sufficiently early. Passing on to discuss certain points connected with the crowding of the population, he remarked that the real problem of civilization had been to render life tolerable in large aggregations, and that this problem was yet only partially solved. Among the difficulties of town life he reckoned—(1) the insufficient supply of fresh air; (2) the mere proximity of persons facilitating the spread of contagious or infectious disease; (3) the getting rid of excreta or waste products; (4) a wholesome water supply to be provided and kept pure.

Mr. Baldwin Latham read a paper *On Hydro-Geological Surveys*, in their bearing on health. He dwelt on the importance of ascertaining the sub-water course, and making certain that the well was on a higher level, so that it could not be contaminated by cesspools or other pollutions. These surveys showed the absolute necessity of sewers being made watertight.

Mr. W. J. Millar read a paper *On the Strength and Fracture of Cast-Iron*. The author described the results obtained in testing cast-iron bars 36 inches span, 2 inches deep, and 1 inch broad. The bars usually broke with straight fractures, but occasionally curved fractures were observed. The average breaking strength of 29 bars showing straight fractures was 3584 lbs., the average strength of 25 bars showing curved fractures was 3551 lbs. Some results of "set" and deflection were given, showing that for successive applications of the same load, 2800 lbs., there was a decrease of set. The principal object aimed at by the author of the paper was to show the relation existing between form and position of fracture, straight fractures taking place at or close to centre of span, and curved fractures occurring at points more or less removed from centre of span.

Sir William Thomson read a paper *On Naval Signalling*, in which he advocated the use on board ship of the fog signalling system instead of the flag system now in use. His method is simply this—to signal according to the Morse telegraphic code by means of two sounds of slightly different pitch. For the long signals he would take a grave note, and for the short signal a less grave note, or what he might call an acute and a grave note for the dot and the dash. Sir William Thomson then gave several signals to show the efficacy of the plan he proposed, and he maintained that the shortness of the time required to make flag signals was far less than could be attained by the phonetic method. Long before the signal flags could be hoisted, the order would be given and read by every ship, and repeated by the different ships in order, back to the admiral. Two sounds of different pitch made in rapid succession was all that was necessary, and to accomplish this all that was required was two steam whistles, each with a different note.

Many other papers of great value were read both in Sections F and G, but as they were mainly technical, or very special, our space prevents us referring to them in detail.

THE CHALLENGER EXPEDITION[1]

THE task which I have undertaken this evening—to give a general sketch, however slight, of the work and results of the *Challenger* expedition in the space of a single lecture—is by no means an easy one, for two reasons. The various lines of inquiry bear on so many different subjects, and these dovetail into one another in such a complicated manner, that it would take many hours to explain them even in the most superficial way. The other reason is that the observations which were made during the *Challenger* expedition have only as yet been very imperfectly examined, and only half digested, owing to want of time, and the great collections in natural history which were brought home in the ship have been only glanced at, and it is therefore scarcely safe for me to use either the observations or the collections as the bases of generalisation. I must therefore this evening, in this address, only be regarded as giving a most elementary idea of the objects of the expedition and its results, and what I say must be regarded as preliminary, and subject to further reconsideration. Still, some new and remarkable facts and phenomena which have hitherto been unknown, or only vaguely guessed at, are sufficiently definite, and I will devote the short time at my disposal to the consideration of one or two of these. The superficial area of this world of ours is about 197,000,000 of square miles, and of these about 140,000,000 are covered by the blue sea at an average depth of 2,500 fathoms—about 15,000 feet. This vast region under the sea has not until comparatively recently excited much curiosity. It seemed to be practically inaccessible, and certain hasty and incorrect assumptions in regard to some of its conditions had reduced it to a barren uniformity and divested it of any interest. The laying of deep-sea cables for the purposes of ocean telegraphy, by bringing to light certain phenomena which threw a doubt upon previous conclusions, stimulated inquiry, and gave rise to new speculation; and the systematic scientific exploration of the depths of the sea by several special exploring expeditions put our knowledge upon a totally different footing. We now know that the sea covers a vast region which is to a certain degree comparable with the land—a region which has its hills, valleys, and great undulating plains; that it has its various soils—widely different materials laid down and accumulated in different places; that it has its climates, whatever the very exceptional conditions of those climates may be; and that it has its special races of inhabitants which depend, like the inhabitants of the rest of the world, upon the conditions of climate and on the nature of the soil for their distribution.

The *Challenger* expedition was despatched on a very special errand—to investigate the physical and biological conditions of the great ocean basins. And, under this general heading, certain more minute instructions indicated the particular questions, physical and biological, which were specially to engage our attention. We were instructed throughout our long course, which extended round the world and traversed the Atlantic and Pacific Oceans and the Southern Sea so far south as it was possible to go without running the risk of being entangled for a winter in the ice—a contingency for which we were not prepared—to select certain stations at convenient distances, and at each of these to determine certain points. We were to determine, in the first place, the exact position of the station; then, with the best appliances at our disposal, we were to determine the precise depth; we were to bring up by means of the sounding apparatus a certain amount of the material of the bottom for microscopical examination and for chemical analysis; we were to bring up a specimen of the water from the bottom for analysis and physical examination; we were to determine the bottom temperature with accuracy; and we were to determine the temperature of the sea at different levels from the surface to the bottom; we were to get specimens, if possible, of the sea water from various depths. Lastly, we were to endeavour, by the use of the trawl or dredge, or any other instrument which might be suitable, at each station to procure a fair sample of the creatures which inhabit the bottom, and in this way to get, if possible, a general idea of the fauna inhabiting the depths of the sea. The instructions of those in charge of the scientific departments in the *Challenger*, both naval and civilian, did not, however, by any means end here. The officers had been selected in order that they might study by the light of their own previous experience the bearings of those various data upon one another, and this was a very serious addition to the work of the expedition. It was found necessary, in order that this might be carried out to its fullest extent, that the instructions given by the Admiralty should be comparatively flexible, and that the details of the working of the ship should be left to a certain extent to the captain of the ship and to the director of the scientific staff, so as to enable them to deviate from any definite line or course when it became desirable for any purpose that they should do so. I have only to add that the equipment of the vessel was such as to leave very little to be wished for, and that the liberal arrangements of the Admiralty, which were admirably carried out by the Hydrographic Department, worked in the most satisfactory way. The *Challenger* left Sheerness on December 17, 1872. She crossed the Atlantic four times during the year 1873, and along a course of nearly 20,000 miles she established 150 observing stations, at each of which, with few exceptions, all the required observations were made. In 1874 she went southwards from the Cape of Good Hope, spending nearly a month among the southern ice, and dipping within the Antarctic Circle, as far as she could with safety, considering the lateness of the season and her unprotected condition. She then traversed the seas of Australia and New Zealand, and made some most interesting observations among the islands of the Malay Archipelago. She arrived at Hong Kong on November 10, having run a course in the year 1874 of upwards of 17,000 miles, along which sixty-six observing stations had been established. In 1875 she traversed the Pacific, with a course of about 20,000 miles and 100 stations; and in the early part of the present year she crossed the Atlantic for the fifth time, filling up here and there blanks in her former observations brought out by increased experience, and reached England on May 24, 1876.

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[1] Report of Address given at the Glasgow Meeting of the British Association, September 11, by Sir C. Wyville Thomson. Revised by the Author.

The cruise on the whole has been singularly fortunate, and it has only been in very unusual circumstances that we have been prevented by the weather from doing our work. The health of the party has been exceptionally good, and the loss by death small. Two misfortunes only befell us in any way sufficiently grave to affect the success of the expedition—one was the death of one of the most zealous and most promising of our civilian staff, Dr. von Willemöes-Suhm, which for long through a gloom over our little party; and the other was the recall of Capt. Nares to take command of the Arctic Expedition. Capt. Nares had acquired, to a remarkable degree, the esteem and confidence of all on board, and although we could not but feel that no other selection of a leader for the Arctic Expedition could have been made in any way so satisfactory, still the fact remained that by the loss of his experience we were greatly crippled. We all trust that he and his bold companions may now be in safety and nearing the goal of their hazardous enterprise; and I am sure that, with the exception of his wife and children, none so earnestly pray for his welfare as his old comrades of the *Challenger*.

Before endeavouring to sketch one or two of the general results at which we have arrived, I wish to give a few words of explanation. I shall have to bring before you various matters which to you may appear novel, but many of these are not entirely original—many have been shrewdly hinted or guessed at from time to time, and many isolated observations have furnished clues which have been eagerly seized by students and made the bases of speculations more or less touching the truth. It is only the unexampled opportunity which we have had at our command which now enables us to place them before you in a connected form, and with a completeness which in some directions at all events precludes the possibility of grave error. It would be impossible for me on this occasion to acknowledge individually the debts we owe to our predecessors, but I must do so in one or two instances. The American Coast Surveyors commenced this work about the same time that we did, and their results are of the greatest possible value. I have only lately become acquainted with a most thoughtful and suggestive paper by Prof. Williamson, which was published so far back as 1847, in the *Transactions* of the Manchester Philosophical Society, in which the origin of organic deposits—one of the most important points which we have to consider—was worked out with great care and skill. In 1869, 1870, and 1871 the observations made in the *Lightning*, *Porcupine*, and *Sheerwater* completely revolutionised our ideas of many of the questions involved. I shall not, however, consider it necessary to quote continually the speculations of my colleague, Dr. Carpenter, on the physics of the ocean, to which, however widely I may differ from his conclusions, I attach a high value; nor the investigations of Mr. Gwyn Jeffreys on the distribution of marine animal forms; for these two gentlemen must be regarded as members of the firm. Among the many points of interest which engaged our attention there were three more especially prominent, and, if possible, I will confine myself to these three, so as to bring my work within a certain limit. The first of these the contour of the bottom and the nature of the deposits now being formed upon it; the second is the more difficult question of the distribution of deep-sea climate; and the third, which is perhaps the most interesting and curious, is the nature and distribution of the peculiar races of animals which are now found at the bottom of the sea. I shall take up these three points in succession, and endeavour very briefly to give an idea of the condition of knowledge with regard to them when the *Challenger* started, and the light which her observations have been enabled to throw upon them.

I need scarcely go into great detail with regard to the contour of the bottom, for the question is mainly a hydrographic one, and would involve use of numbers which would be scarcely suitable for a public lecture. As I have said already, the average depth of the ocean is somewhere about 2,000, or probably 2,500 fathoms. A very large portion of the ocean has a depth somewhat less than this, and a depth of 2,000 fathoms appears to be common. Where it is 2,500 or 3,000, we would appear to be going into submarine valleys, with the exception of the North Pacific, where there is an enormous extension of water of great depth, in many cases going beyond 3,000 fathoms. In the Atlantic, a great part of the northern portion has a depth of about 2,000 fathoms, with a middle ridge which passes down from Greenland, and includes the various groups of islands and single islands to Tristan d'Acunha, and probably beyond it. In the South Atlantic, on each side of this ridge, which is there called the "Dolphin Rise," in compliment to the American ship which first surveyed it, there is a trough which runs to a considerable depth, usually down to 3,000 fathoms, and these form marked depressions roughly parallel with the axes of the South American and African continents. I will frequently allude to the Atlantic, as I have no time to enter into detail with regard to the rest of the seas, and we had the best opportunity of working it. Now, the bottom of the sea is covered with certain deposits. The whole bottom of the sea, so far as we are aware, is gradually receiving certain accumulations, and these accumulations are giving rise to formations which we look upon as the rocks of the future. We know by our knowledge of the science of geology that the whole dry land, as we have it at present, is composed—with the exception of certain volcanic rocks, which may be, in many cases, metamorphosed sedimentary rocks—of stratified beds laid down at the bottom of the sea. We know that the material of these beds is to a certain extent derived from the gradual disintegration of the land, and we look upon the sea as the great restorer of the solid material which is to form future islands and continents, as the bottom of the sea becomes raised up at some future time above the level of the ocean. Now, the whole of the sea-bottom is receiving these deposits, and it was one of our great objects in the cruise of the *Challenger* to determine what these deposits are, under what laws they are being laid down, and what the relation of these modern deposits may be to the ancient deposits, which form the solid crust of the earth. We were well aware that there was a perpetual disintegration of the land going on by rivers and by the action of the sea round its coasts, and that the material worn off the land was being carried away by the ocean and laid down at some distance from the land, and that the material was being selected and arranged according to some definite laws. Accordingly, when we came to test this, we were not surprised to find that the *débris* of the land extended for some hundreds of miles from the land out to sea. We found clays being formed, and various deposits, differing according to the material from which they were derived, and mixed up with the *débris* of animals living in the places where these deposits were being laid down. Within a certain distance of the land we found the deposits formed to a great extent of this peculiar shore material.

Many years ago it was determined by observation, even previous to the soundings for the first Atlantic cable, that over a great part of the North Atlantic a very remarkable deposit was being laid down—a deposit now known as *Globigerina* ooze. This deposit consists of the shells of minute *Foraminifera*, principally belonging to one genus—the genus *Globigerina*. This, as we found it in these deposits, was a small chambered shell extremely minute, about a millimetre in diameter, and these shells were found in enormous quantity. When dry, the ooze was something like fine sago, with little round shells falling from one another, and showing that the deposit was formed almost entirely of such shells. Some other genera were mixed with them, but the great mass were *Globigerinæ*. When we took up by any means material a little below the surface of the sea-bottom we found the *Globigerina* shells were becoming broken and compacted together so as to form a close and nearly amorphous mud, in which there were very many complete *Globigerinæ* and many pieces of the same. The whole of this deposit was composed almost entirely of carbonate of lime, and the only rock which this could possibly form was a limestone. It therefore appeared that over a very large portion of the North Atlantic, and over many other parts of the world where these observations had been made, this limestone was being laid down. Further observations showed that the chalk was composed of very nearly the same material, and the analogy between these modern formations and the chalk became very apparent. During the voyage of the *Challenger* we had many opportunities of bringing up this modern chalk, and the question which was always before our minds was one which had been mooted before we started—Where did these creatures live—did they live upon the bottom of the sea? or did they live on the surface, their shells falling to the bottom after death? Until lately none of these animals, or very few, had been found alive upon the surface. It was our general impression that they lived on the bottom, where we found their dead shells. Mr. Murray, one of my companions in the *Challenger*, has paid particular attention to the structure of the material brought up from the bottom—its composition, and the sources from which it was derived. He worked the tow-net and the sounding apparatus together during the voyage, and came to a decided conclusion, one to which we are absolutely forced to agree with him. The tow-net upon the surface, and particularly at a little below the surface—that is to say, to the depth of a few fathoms, or even to a hundred fathoms—takes enormous numbers of these *Foraminifera*, which make up the *Globigerina* ooze alive. The *Globigerinæ* themselves, in many seas, are most abundant, and they present characteristics totally different from the shells as we find them below; so that I think there cannot be the slightest doubt that these shells live on the surface, and a little below the surface, and that the whole material at the bottom composed of these shells is derived from the surface. When we find these shells at the bottom they are little globules all united together, and forming a little compound mass of globules. These are rough on the surface, and perforated with minute pores. The cavity of the shell contains a little reddish material, which, at first, we were inclined to suppose was the remains of the body of the animal. When the *Globigerina* was found on the surface, the shell was of the same form, but instead of being white and opaque, it was perfectly clear and transparent. A raised frill on the shell forms a hexagon round each minute pore and runs into six points, and from each point a long spine projects—in fact the shell bristles with long spines running out in every direction, the axes of the spines on each chamber meeting in the centre of the chamber. The shell has a little animal in the interior of it, and that animal consists of a particle of gelatinous matter like the white of egg, and when alive this matter runs out of the holes on the surface of the shell to the end of each of the spines, where it absorbs minute particles of organic matter floating in the water. The *Globigerinæ* seem to be of the same specific gravity as the water, their weight being reduced by large oil-globules scattered in quantity through their substance; they exist in myriads on the surface, while they are perpetually dying and sinking to the bottom. Finding them so abundant in a living condition on the surface or a little below, and finding none living at the bottom, there seems to be little room for doubt that the *Globigerina* ooze is due simply to the accumulation of the dead shells of the inhabitants of the surface and of moderate depths. We should therefore at once come to the conclusion, if this be true, that the formation which arises from their accumulation ought to be as universal as they are themselves. Singularly enough, this is not the case, and this is one of the most curious points which we have determined. When we go to a depth of about 2,000 fathoms we find that the shells at the bottom are becoming, as it were, rotten or yellow, they have not the same white clear appearance which they had in shallower water, and if we go to a depth of 2,500 fathoms or so, we find no shells whatever, but that the bottom consists of a homogeneous red mud, which, instead of consisting of carbonate of lime, is formed of the materials of ordinary clay. Now, as a very large portion of the sea is below 2,000 fathoms in depth, probably by far the greatest portion is being now covered by red clay, and not by calcareous formations. The question at once arises, How is it possible that these calcareous formations are stopped at a certain point and replaced by red clay? There is no doubt that the calcareous formation is arrested by the carbonate of lime being in some way or other removed from the shells of these creatures. When we come to a certain depth the carbonate of lime is dissolved, and we have a fine red clay instead. The cause of the removal of the carbonate of lime is as yet rather obscure. We were at first inclined to believe that it is removed by excess of carbonic acid in the water. If the water contained an excess of this acid it would dissolve these shells, and it is just possible that the excess of carbonic acid in these depths may remove the carbonate of lime. We also find a large quantity of sulphate of lime dissolved in the sea, and it is just conceivable that a considerable amount of sulphurous acid may be percolating through the crust of the earth at various places, and that it may be converted into sulphuric acid, which would dissolve the carbonate of lime. But whatever be the reason there cannot be the slightest doubt that on reaching 2,000 fathoms depth the lime is gradually removed, and we have the red clay. There is another important and curious question arising—namely, where does the red clay come from? The red clay consists of the silicate of alumina and iron. This compound does not exist in any quantity in the shells in that particular form, and there is no doubt that some complicated changes taking place in the sea at this moment are producing this silicate of alumina and peroxide of iron. There is one very remarkable thing which has been observed by Mr. Murray and Mr. Buchanan, who have been watching this matter with great care, and that is that all over the sea there is a large quantity of pumice. Volcanoes—either sub-ærial or sub-marine—either exposed to the air or under the water—are perpetually throwing out material from the crust of the earth, and the pumice, which is the froth of the lava—lava divided minutely and containing bubbles either of steam or air—is very frequently so light as to float freely in water; and almost wherever we were, in all parts of the world, we found that particles of this pumice had been caught by the sea, and so moved about in currents slowly over the surface of the ocean. In almost all parts of the sea, the trawl or the dredge brought up bits of pumice which had been waterlogged and had fallen down to the bottom, probably after swimming or floating about for a very great length of time. This pumice was constantly in various stages of decomposition, and its decomposition like that of all felspathic minerals must result in the production of a clay. It is very certain now that these calcareous formations which are being produced by the animals floating upon the surface of the sea and falling to the bottom, and there accumulating, are by no means universal, but that besides these there are huge formations of clays which are capable of giving rise to important formations of schists being produced at the bottom of the sea at the present day. Over the whole bottom of the Pacific, or a very large part of it, we find red clay, and particularly in the North Pacific, where there is a great depth of water. The red clay has all through it nodules, which vary from the size of sago or a canary-seed to the size of a child's head or an orange, composed of nearly pure peroxide of manganese. These are found in enormous quantity. The trawl sent down to the bottom in those regions brings up masses of concretions, much resembling lumps of the mineral known as *wad*, almost all of which contain as a kernel in the interior a fish's tooth, or a little bit of sponge, or some fossil of some kind, which has formed the nucleus round which the manganese has accumulated. This is altogether a most peculiar and novel observation. In the Atlantic and all over the bottom of the sea we find manganese in minute bits, but in the North Pacific particularly these pieces are in very great quantity and attain a large size. This is a phenomenon which we are as yet unable to explain, and I do not know that there is any analogous instance in any of the older formations.

Along with the *Foraminifera* we have living in the sea a great number of extremely beautiful little organisms, which are known under the name of *Radiolarians*. Instead of these having calcareous shells, they have silicious shells—sometimes external, sometimes internal, but very generally presenting extremely beautiful forms. The *Foraminifera* appear to live mainly upon the surface, or a little below it. In regard to the *Radiolarians*, it seems to be somewhat different, for when the tow-net is dragged along the sea even at the depth of 1,000 fathoms, we find that the number of *Radiolarians* increases, and that the size of the specimens of the species which are found on the surface is rather greater; and many forms occur at those great depths which are not found on the surface at all. Therefore we are inclined to believe that the *Radiolarians* live all through the sea, and down to its greatest depths, which may be something like five miles. Now, you can easily understand that these things, living in this way, add considerably to the formations which are taking place at the bottom. We even found a formation which has been called by Mr. Murray *Radiolarian* ooze, on account of its consisting almost entirely of the remains of *Radiolaria*. The mode of formation of this ooze is peculiar; it seems that the *Foraminifera*, living only near the surface, have their shells entirely dissolved before they reach the bottom; the red clay is laid down as usual, whatever may be its source; but the shells of the *Radiolarians*, living throughout the whole of the vast depth, are so numerous as entirely to overcome and mask all the other constituents of the bottom. This formation, however, only occurs at very extreme depths, and it is therefore apparently in patches at the bottom of the sea. In the Southern Sea, where the depth is not so great as the Pacific or Atlantic, we find that the surface, instead of being covered with *Radiolarians* is covered with a set of minute plants which have silicious coverings. Those plants are living on the surface in enormous quantity, and consequently dying on the surface. And when you drag the dredge or trawl over the bottom it comes up with a white matter, which looks at first extremely like chalk, though it is formed entirely of silica. There are many other points of great interest connected with these recent deposits, but my time will not allow me to refer to them. I will, therefore, now pass on to the second question of special prominence—the climates of the sea.

The temperature at the depth to which I alluded—namely, 2,500 fathoms—is very low. Over the whole bottom of the Pacific and the Atlantic, and those portions of the Southern Sea which we have examined, the temperature is usually a little above the freezing-point. Down in the valleys it sinks to perhaps pretty near the freezing-point in some places, and in some very few places it sinks a little below it, but it is only in one or two places in the Atlantic and Pacific we find such extremely cold water. Over the elevations the temperature is somewhat higher; but in the Atlantic and the Pacific, as a rule, the rise of temperature on the ordinary elevations of the bottom of the sea is not above two or three degrees. The temperature of the bottom of the sea is, therefore, as a rule, a little above the freezing-point. When we examine the temperature of such an ocean as the Atlantic, from the surface down to the bottom, we find that it gradually falls. On the surface its height is according to the season of the year, according to the latitude, and according to the heat of the sun at the locality observed, or at that from which the surface-water is immediately derived. The temperature often rapidly falls for a certain distance and then it more gradually falls to a depth of about 500 fathoms, when it has a temperature of something like 45°. That is a very general temperature for a depth of about 500 fathoms. From that point downwards the temperature very slowly and gradually falls, and it falls till it reaches a temperature of 37° or 34°, or, as I have said before, sometimes below the freezing-point. Now, the consequence of this is that we have a very uniform as well as a very low temperature at the bottom of the sea, and we shall see shortly the result of this on the distribution of animal life. It is a uniform temperature, but it is a temperature which varies within certain limits. The question comes—Whence does the ocean derive this peculiar temperature? and this is a question of very great difficulty, and one which I have not to-night sufficient time to go into in detail, but I shall merely give you a general idea of the impression which is on our minds after the observations of the *Challenger* with regard to the sources of temperature in the Atlantic. The surface, as I have said, is affected by the heat of the sun, and by the conditions of the latitude down to perhaps about 500 fathoms. It is also very greatly affected by currents which are moving through the sea, and which are mixing water of different temperatures, and bringing water of different temperatures from different places. There is one set of currents which is particularly marked and which tends to spread warmth over the surface of the northern and southern seas, and modify the ocean temperatures. These are the great currents which are running from east to west driven by the trade winds blowing along the equatorial region and driving before them the equatorial water. They are met by the great continents—one is met by Cape San Roque in South America, in the Atlantic, and against Cape San Roque it divides: one portion going northward and another southward. In the Pacific the current is met by the coast of Asia, and in the same way one portion runs northwards and the other southwards. Thus warm water, being driven to the north and south, becomes mixed with colder water, and the temperature is modified and ameliorated by it. It is likewise affected by other currents which are produced by various reflections against coasts and other obstacles. In this way we have water moving about on the surface and conveying temperature from one place to another, and rendering the temperature of these upper 500 fathoms extremely irregular. In the Atlantic we find that from this point—about 500 fathoms—to the bottom the temperature steadily decreases until it comes down to near the freezing-point, no matter the surface-temperature or the latitude. We have come to the conclusion that this great mass of water is moving from the Southern Sea, and there seems to me to be very little doubt—although this matter will require to be gone into carefully—that the reason why this water is moving from the Southern Sea in a body in this way is that there is a greater amount of evaporation in the North Atlantic and over the Northern Hemisphere generally, than there is of precipitation, whereas it seems almost obvious that in the Southern Hemisphere, in the huge band of low barometric pressure round the South Pole, the precipitation is in excess of the evaporation. This is an extremely simple way of accounting for this mass of cold water which it has been hitherto found impossible to account for on any reasonable theory.

There is a minor phenomenon connected with this grand system of circulation which passes partly through the atmosphere and partly through the ocean, which is extremely pretty, and of this I will endeavour to give you a single illustration; and in order to understand it fully I will ask you to imagine for a moment a terrestrial globe and the relations in volume and position which the oceans and the continents bear to one another. You remember the vast accumulation of water round the South Pole, and in the South Pacific; and the "land hemisphere" almost in the centre of which we now stand, with the two great gulfs, the Pacific and the Atlantic running up into it, almost cut off by land and shallow water to the northern end, but opening widely to the Southern Sea. Now imagine the depth along a line joining Cape Horn with the Cape of Good Hope to be 3,000 fathoms, the bottom temperature being 30°, and the temperature at 2,500 fathoms 32°, and suppose a continuous barrier to extend between the two capes to the north of this line, rising 500 fathoms from the bottom; it is clear that if the movement of the mass of cold bottom water be constantly from the south to the north, no water colder than 32° can ever enter the Atlantic, and however deep portions of that ocean may be, water under that temperature can never be found in it to the north of the 2,500 fathom barrier.

Although this is an imaginary case, at least one which is scarcely in nature so simple as I have represented it, we find the same law acting perpetually. In various parts of the world there are little isolated seas, and circumscribed basins of the great ocean, surrounded by such barriers, and we can tell at once the height of the lowest part of the barrier by the temperature of the bottom-water of the basin, for we know that it must correspond with the depth at which the like temperature occurs in the outer ocean from which the basin derives its supply.

I have now only a few minutes left to refer to the last of the three questions selected for consideration, the distribution and nature of the deep-sea fauna. The deep-sea is by no means barren, but on the contrary a fauna very remarkably constituted and comparatively rich, is universally distributed even to the greatest depths. It was our impression that when we examined this fauna we should find it very analogous to that of the ancient chalk, for we believed, and we believe still, that the deposition of chalk has been going on continuously in various parts of the ocean, from the chalk period to the present time. In this expectation we were to a certain extent disappointed, for the species found in the modern beds are certainly in very few instances identical with those of the chalk or even with those of the older tertiaries. But although the species, as we usually regard species, are not identical, the general character of the assemblage of animals is much more nearly allied to the cretaceous than to any recent fauna. You have in the Clyde district some extremely interesting little localities—one for instance in Loch Fyne near Inverary, and another at Oban—where animals are found in shallow water which are usually only found in deep water, and other animals which are chiefly confined to the Arctic Seas. Prof. Edward Forbes called these animals *Boreal outliers*, and believed that the little basins in which they occur in this country—which are always cherished dredging spots for naturalists—are spots where, owing to the configuration at the bottom and to other causes, patches of the old fauna have been entangled and retained at the close of the glacial period.

Here and there on the surface of the earth we seem to have, in like manner, what we may call *Abyssal outliers*, spots where, during some process of elevation, the abyssal fauna has been caught and kept at an accessible depth. Such spots occur off the coast of Japan, near Yokohama, at various places among the Philippine Islands, off the coast of Portugal, and off the north coast of Scotland, and from each of these strange and beautiful things were brought to us from time to time, which seemed to give us a glimpse of the edge of some unfamiliar world. Among these were the lovely and wonderful *Euplectellas*, and glass-rope *Hyalonemas*, and bird-nest-like *Holtenias*, and many others of the hexradiate order of sponges, the representatives, and no doubt the descendants, of the *Ventriculites* of the old chalk; and the graceful sea-lilies belonging to the *Pentacrinidæ*, and the *Apiocrinidæ*, whose aspect carries us back at once to the clays of the Lias and the terraced limestones of the Jura.

The fauna of the deep sea is wonderfully uniform throughout, no one who has once seen it can fail to recognise this general uniformity, whether he examines it in the middle of the Pacific, in either trough of the Atlantic, or in the Southern Sea; and yet, although in different localities the species are evidently representatives, to a critical eye they are certainly not identical, and I believe that one of the most important lines of inquiry which have been opened up to us by these investigations is the range and amount of variation, or possibly the passage of one apparent species into another over this vast area, remoteness in space being, when we consider the conditions of migration with the accompanying change in surrounding circumstances, equivalent to lapse of time.